2.5 Genetic Technologies

In 2000, the remains of an unidentified Canadian soldier who died during the First World War (1914–1918) were moved from their burial place near Vimy Ridge in France to a special tomb in front of Ottawa's National War Museum. This symbolic "Tomb of The Unknown Soldier" was created to honour the thousands of Canadians who have died in battle and, in particular, those who died without being identified or found.

Methods used by militaries to identify their dead have changed with advances in technology. You may be familiar with the term *dog tag*, which refers to an identification number engraved on a small metal plate that soldiers wear around their necks. Metal dog tags were first used in World War I because, unlike human bodies, they could withstand the force from some bomb blasts and gunfire. Identification tags can be collected after a battle and used to trace which soldiers were killed in an attack. However, as you can imagine, there are many variables in using identification tags as a way to identify troops—tags may fall off, become buried in debris, and be taken by other people at a battle site.

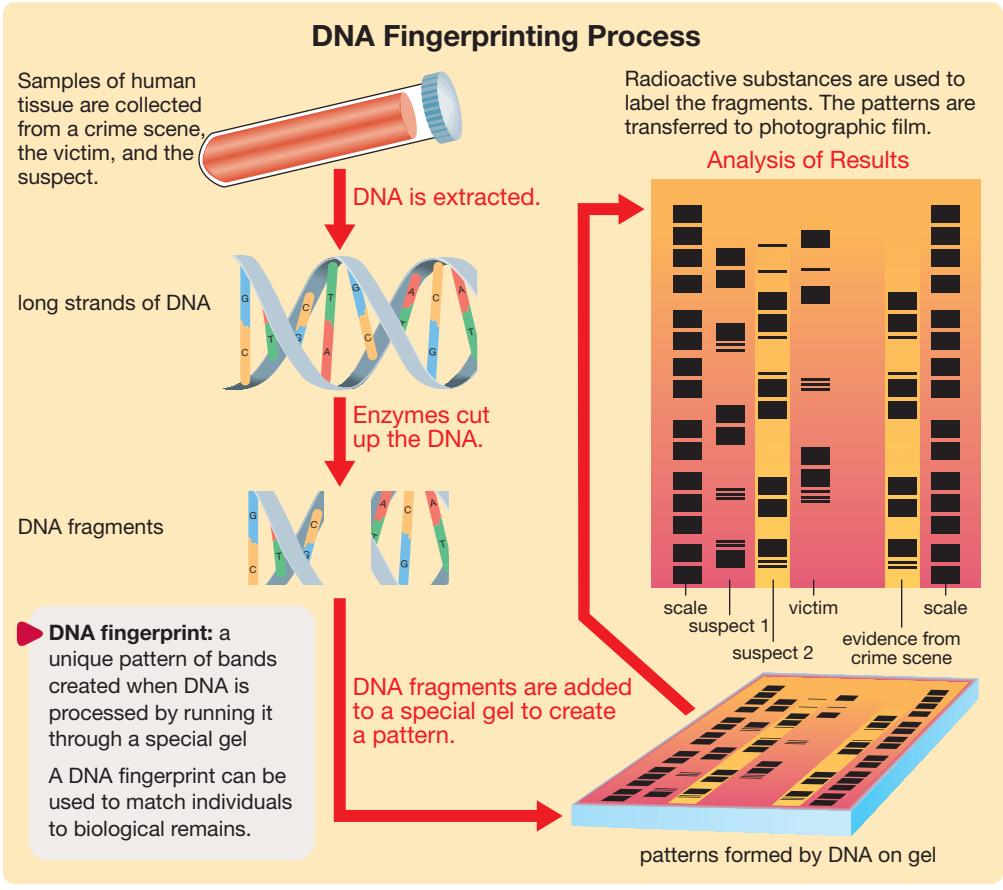
Until recently, an external examination of the body was the most efficient identification method available. The Canadian military has started using DNA obtained by taking a blood or saliva sample from new recruits as a way to store soldiers' biological information for use in identification. Every cell of a person's body contains DNA. When the DNA is extracted and processed it forms a pattern unique to each individual, so examining a person's DNA can be an accurate way of identification. Using libraries of DNA patterns can be a reliable way of keeping track of military personnel, making the possibility of another "Unknown Soldier" a thing of the past.

Advances in the understanding of genetics and the use of genetic technologies have created a scientific revolution. Genetic technologies are being used to identify, treat, and prevent hereditary diseases; to develop new medicines; to solve crimes; to identify individuals such as unknown soldiers; and even to re-design organisms. Although the science of molecular genetics is just over 50 years old, these uses have already made significant impacts on society. Some people worry about the safety and ethics of using these technologies. In this lesson you will learn about and research some genetic technologies. From several perspectives you will be asked to look at issues created with the use of genetic technology. You will also explore the potential ethical implications of using these technologies by performing a risk-benefit analysis of a genetic technology and making a decision about the extent of its use.

DNA Fingerprinting

Analyzing DNA has become a useful and popular tool in forensic investigations. Using DNA testing to solve a crime or to prove a person's innocence has been the subject of many books, popular television shows, and movies. This technology works because of the uniqueness of each person's DNA. In order to identify a person, strands of DNA are isolated from that person's cells and cut into smaller fragments. Then these DNA fragments are separated as they move through a special gel placed within an electric field. As DNA fragments are pulled through the gel by the charged ends of the field, a pattern of bands form. The DNA pattern that appears on the gel for a tested individual is as unique as the swirling patterns of an individual's fingerprints. That's why this process has been called DNA profiling or **DNA fingerprinting**. Identical twins or triplets have the same DNA fingerprints. A DNA fingerprint can be analyzed and compared to DNA collected on a battlefield or at a crime scene, matching evidence to soldiers' remains or to suspects. Similar processes are also used to determine whether people are genetic relatives or to carry out wildlife forensics.

The uniqueness of a DNA fingerprint and the information gained from a person's DNA can be stored in a computerized database. In most countries, only criminals have their DNA profiles stored in computerized DNA databanks. Some people would like to see everyone's DNA stored in a DNA bank. A more complete databank of DNA could be very useful, since a computer can quickly search the stored information. As a result, police would have a better chance of matching evidence from a crime scene that contains DNA—cells, tissue, hair, and saliva—to individuals in the database.



Practice

45. Health benefits provided by employers and health-insurance companies help pay an employee's wages when the employee becomes ill. Explain how a genetic test could be used against a prospective employee or someone applying for health insurance.

46. Genetic information—including the identification of genes that make it more likely to develop certain diseases—can be revealed about an unborn baby by performing an amniocentesis. Describe one risk and one benefit related to the use of genetic test results from an unborn baby.

47. DNA for testing can be collected from a small amount of blood, hair, saliva, and other body fluids. Do you think authorities have the right to collect samples and perform DNA profiling on an individual without this person's permission? Do you think that an individual has the right to refuse to provide a DNA sample for authorities? Once a DNA profile or a genetic screen has been performed, is it possible to keep the results private? Explain your answers.

Transgenics

The mice in Figure A2.21 are glowing because some of the genes they possess have been altered to produce a unique protein with the ability to glow when exposed to ultraviolet light. Jellyfish produce a protein that enables them to glow in certain light, and scientists have isolated this jellyfish gene and then used a modified virus to insert it into the DNA of a mouse embryo. When the mouse embryo develops, each cell has the instructions to make the luminescent jellyfish protein to create a mouse with the ability to glow.

Figure A2.21

The process of intentionally altering the genetic traits of an organism is called genetic modification. As you learned earlier, genetic modification can be done through traditional selective breeding within a species by cross-breeding between closely related species. However, it is much faster to transfer the isolated genes from one species into another species in a process called **transgenics**. People often use the terms **genetic engineering** and transgenics interchangeably, but genetic engineering is a more general term, which includes technology that is hundreds of years old. The result of transgenics is called a **genetically modified organism** or **GMO**.

- **transgenics:** a type of genetic modification in which the gene or genes from one species are transferred and spliced into the DNA of another species
- **genetic engineering:** the modification of genetic material through the actions of people, including selective breeding and modern techniques outside the normal reproductive process of organisms
- **genetically modified organism (GMO):** an organism whose genetic material has been deliberately altered through transgenics

Imagine having the ability to combine the traits from one organism with the traits of another organism. This technology is used to create new foods, medicines, or materials with the potential to increase crop yields, improve health, cure diseases, and produce new products. Many modifications to organisms are being made by genetic engineering, including crop plants containing genes from other organisms that naturally produce their own pesticides. Another modification is bacteria containing a human gene capable of producing insulin required by diabetics.

Scientists are also using this technology to develop pigs with human genes that produce the necessary antigens to make pig organs more compatible with humans and, therefore, more useful for organ transplants. Some researchers are developing goats with genes associated with the silk a spider produces so that goat milk has strands of very strong spider silk for making rope.

The ability to alter organisms with transgenics has an almost limitless number of possible applications. Many industries and companies are interested in this technology, and there is a huge potential to produce both useful and novel inventions that can be sold to make a profit. For example, if the glowing jellyfish gene is combined with an evergreen tree, the inventors could sell glowing Christmas trees that don't need strings of lights.

Opinions on genetic technologies come from many perspectives. From an ethical perspective, some people may question creating genetically modified organisms because they have concerns about harming living organisms. Other people are in favour of transgenics from an economic perspective because the products of this technology have proven to be valuable.

Opposition to the use of this technology has also come from a scientific perspective because some people fear that genetically modified organisms can produce unexpected effects on ecosystems if they are released accidentally. For example, there is a concern that herbicide-tolerant canola may cross-pollinate with related weeds to produce weeds that are herbicide-tolerant. One type of corn has been genetically modified to produce a pesticide. A scientific study has indicated that this corn unfortunately caused the death of monarch butterfly caterpillars.

Many people are opposed to transgenics because they are afraid that some scientists may use genetic engineering to create monstrous creatures like the chimera. The chimera is a mythical beast made from the parts of several different animals. These genetically modified organisms could endure lives of suffering because of genetic experiments. Even more fearful is the possibility that these transgenic organisms could become dangerous either by accident or on purpose. For example, disease-causing organisms could be engineered to become more infectious and deadly by combining the traits of two or more pathogens and then used as a weapon. Genetically modified disease-causing organisms designed to infect people and make them sick or kill them are called **bioweapons**.

People who have concerns or fears about transgenics often refer to works of science fiction where the use of technology goes horribly wrong. Examples include *Frankenstein* and *Jurassic Park*. Foods that have been genetically modified are sometimes even called "Frankenfoods" by people fearful of this technology.

bioweapons: genetically modified disease-causing organisms designed to infect people and either make them sick or kill them

Practice

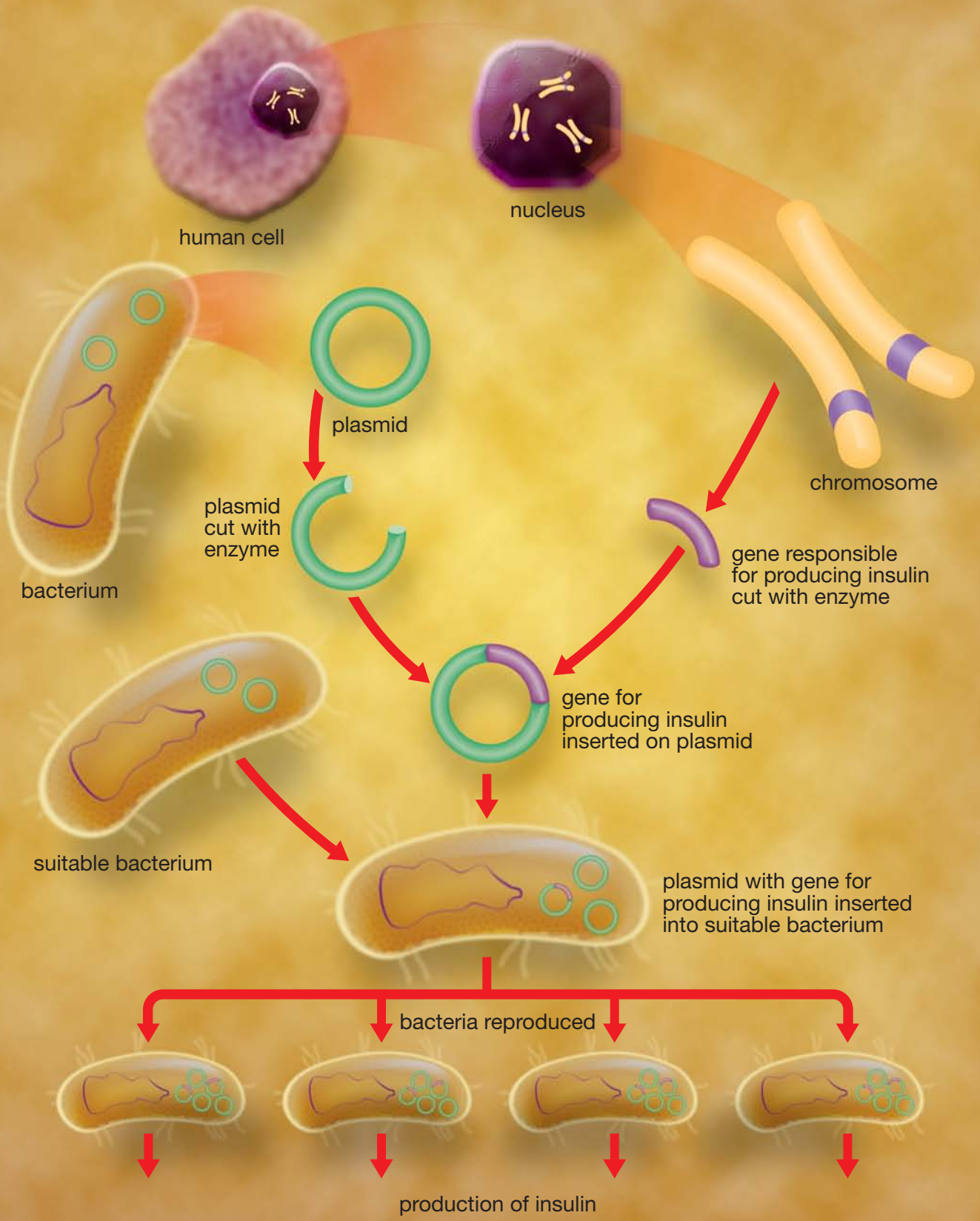
48. At the time this textbook was written, Canada did not require manufacturers to indicate ingredients on their food labels that originate from genetically modified organisms. European Union countries do require such labels. Genetically modified (GM) foods are almost impossible to distinguish from non-genetically modified foods because they usually look the same. Herbicide-resistant GM versions of corn, canola, flax, soybeans, sugarbeets, and wheat are grown in Canada. You have most likely eaten some of these genetically modified foods. Do you think food manufacturers in Canada should be required to indicate genetically modified foods in their products? Explain your answer.

49. A research facility has produced a mouse that does not produce hair and does not initiate an immune response that would reject the ear grafted on its back. The ear grown on a mouse could be used to replace an ear that a person has lost due to an accident. Transgenics could be used to insert human genes into mice, pigs, or other animals to make them even more suited to growing organs that would not be rejected when transplanted into humans. From an ethical perspective, do you think transgenics should be used to create animals with organs compatible for transplanting into humans? Explain your answer.

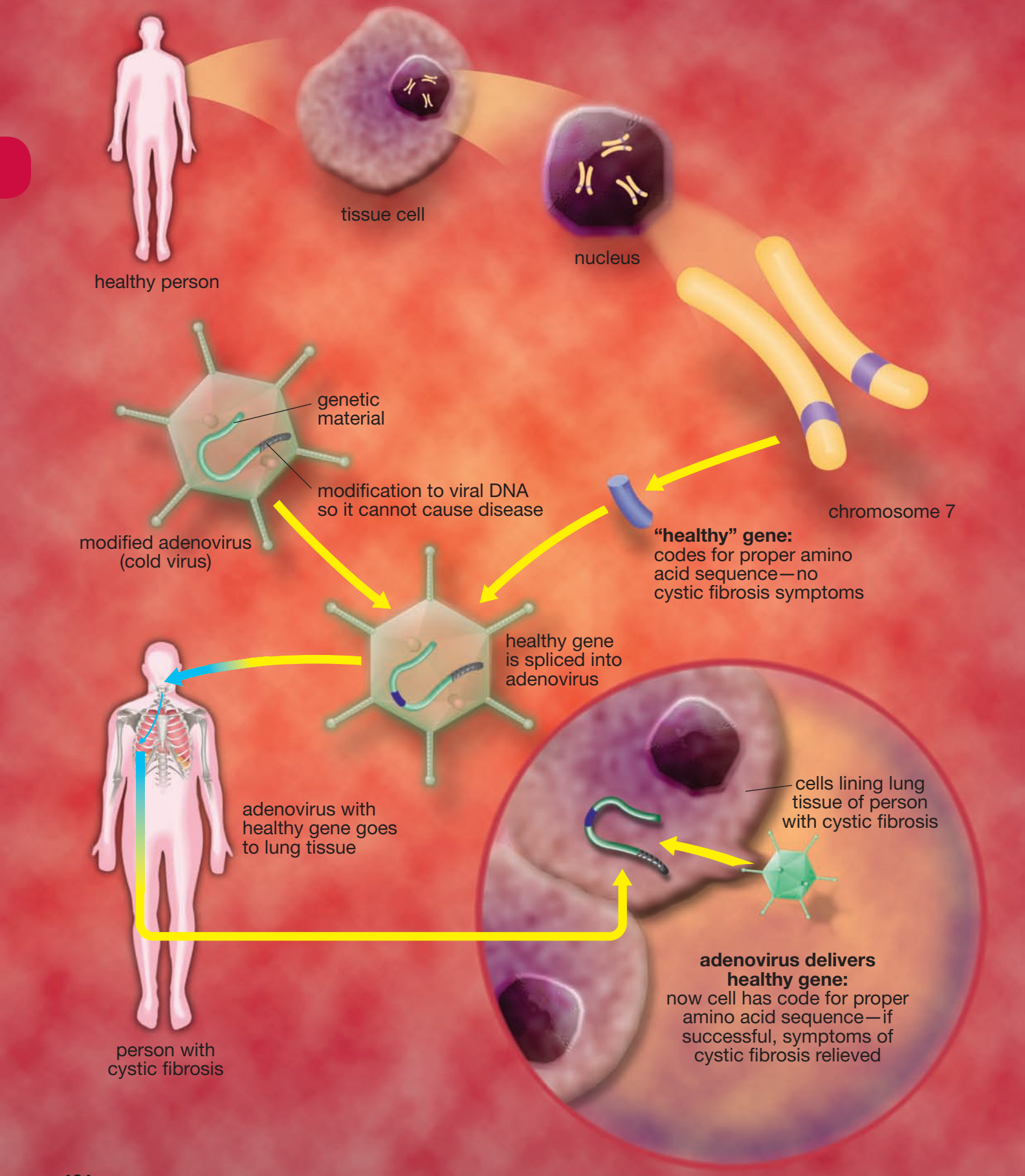
Applying Transgenics—Medicines and Gene Therapy

Scientists have begun using transgenics to produce medicines instead of having to chemically manufacture medicines or have them collected and extracted from plant or animal parts. Extraction from animal parts is a lengthy process that requires a large input of animal tissue to yield relatively little product. The extraction process requires the use of many noxious chemicals, and the insulin extracted from animals can trigger allergic reactions in some patients.

Producing Insulin Through Transgenics



Gene Therapy for Cystic Fibrosis



Scientists can now isolate the gene in a healthy human that produces a substance lacking in other people, such as the gene that produces insulin. Enzymes are used to cut a sample of the healthy individual's DNA into pieces. The segment of DNA with the needed gene is isolated, and the gene is inserted or spliced into a plasmid removed from bacteria. DNA containing the genes from two or more organisms—such as combined plasmid with inserted human DNA—is called **recombinant DNA**. The recombinant plasmid is put into a bacterium and huge amounts of this new bacterium are grown. This creates a strain of bacteria that produce insulin. The insulin can be collected and given to people who have diabetes.

- **recombinant DNA:** DNA containing the genes spliced from two or more organisms
- **gene therapy:** the technique of using a vector, such as a virus, to repair or replace defective genes in the treatment and possible cure of genetic diseases

Genetic diseases are difficult to cure because they are caused by a defective copy or copies of an allele present in every cell of a person's body. Some people with genetic diseases can be treated by being given a product that their bodies cannot produce on its own. For example, people with hemophilia cannot produce a type of blood-clotting protein, so they have to receive several injections of clotting proteins per week. Scientists are working on ways to repair or replace non-functioning genes so that genetic diseases can be treated more effectively or even cured. Using genes instead of drugs to treat or cure a disease is called **gene therapy**.

Gene therapy works by identifying and isolating a desired gene from one individual and using it to replace a non-functional gene in another individual. In order for the isolated therapeutic gene to be effective, it must get spliced into the DNA of the person with the non-functional gene. A gene cannot be directly inserted into a person's cells, so one way to insert the therapeutic gene into cells that need to produce the missing protein is to use a vector, such as a virus. Scientists have taken advantage of the way that viruses deliver their genes when they infect cells. The disease-causing genes of the virus are removed and the therapeutic gene is spliced into viral DNA. Patients are infected with many of the altered viruses. Each virus injects the recombinant DNA—containing the therapeutic gene—into a patient's cell to allow the cell to produce the missing or defective protein.

"Bubble Baby" Cured Using Gene Therapy

Figure A2.22 shows a small girl named Salsabil, who had a mutation to the one gene that is responsible for producing an essential enzyme called adenosine deaminase, or ADA. Salsabil did not have a trace of the ADA enzyme in her body because the mutated gene was defective. Since ADA is responsible for producing T-cells and B-cells, Salsabil had virtually no immune system and had to live the first seven months of her life in a plastic bubble to protect her from pathogens. This is why this illness—severe combined immunodeficiency or SCID—is often called "bubble baby syndrome" in the media.

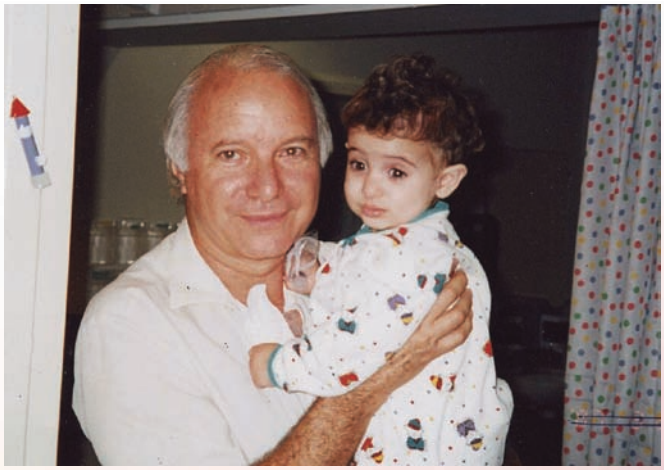


Figure A2.22: Dr. Shimon Slavin holds a healthy Salsabil prior to her second birthday.

Children with SCID used to be treated with injections of the ADA enzyme every two days or they received a transplant of healthy bone marrow from a compatible donor. If neither treatment was possible, the only alternative was for the children to live their lives in artificial, germ-free environments.

In Salsabil's case a team of doctors and medical researchers, led by Dr. Shimon Slavin, were able to use gene therapy. A sample of Salsabil's bone marrow cells were extracted and mixed with a genetically engineered virus containing a healthy copy of the defective gene. The virus injected the human gene directly into the nucleus of the bone marrow cells. Before the healthy bone marrow cells were transfused back into Salsabil, the medical team subjected her to a mild form of chemotherapy to suppress her defective bone marrow cells. When the healthy cells were introduced to Salsabil's body, they had not been subjected to the chemotherapy and had an advantage—they began to take over and grow rapidly. Within months, Salsabil had T-cells and B-cells working together to produce antibodies. A year later, Salsabil returned to her family. She was effectively cured of SCID.

Practice

50. Describe some concerns that arise from using viruses to carry and insert therapeutic genes into patients.

51. The use of gene therapy is currently focused on treating and curing genetic diseases. As more genes become identified and studied and this technology becomes more advanced and accessible, some people who can afford this technology might seek to use it to alter genes that control traits—such as height, intelligence, or athletic ability—other than those causing disease. People might use this genetic technique to insert desirable genes either into themselves or into embryos before they begin to develop. Describe some risks associated with using gene therapy techniques for goals other than treating and curing diseases.

52. Insulin can now be produced by genetically engineered bacteria. Before these bacteria were approved, insulin could only be obtained through extractions from the pancreases of pigs or other livestock. List some benefits of using genetically engineered bacteria instead of animal glands.

53. Choose one of the following problems to design an experimental procedure to investigate a characteristic of a genetically modified organism. In your experimental design, list the steps you would take to carry out your experiment. State the manipulated variable, responding variable, and at least three controlled variables.

a. A genetic engineering company has produced a genetically modified variety of onions. The company isolated the protein that makes our eyes water when onions are cut, and people who work for the company believe that they can make the gene that produces the protein non-functional. This genetically modified (GM) onion will not make people's eyes tear when they cut the onion. Some researchers are worried that removing this gene will affect the taste of the new GM variety. Design an experiment to determine whether the onion's flavour has been affected by removing the eye-watering gene.

b. Genetic engineers have isolated a gene from a cold-water fish called a flounder. This gene produces a protein that acts like antifreeze—it prevents the fish from freezing in the icy waters where it lives. Researchers have inserted the gene responsible for producing the antifreeze protein into a tomato plant's genetic instructions to make a new variety of tomatoes more resistant to frost.

If the new variety of tomatoes proves to be effective and popular, then fewer tomatoes will spoil during shipping. Design an experiment to determine whether the new tomato variety is more resistant to frost than non-modified varieties.

c. Agricultural scientists have used the genetic modification technology of gene splicing to insert a gene into a canola plant that makes the canola more resistant to strong chemical herbicides. A crop of GM canola can then be sprayed with a strong chemical herbicide to kill competing weeds and leave the canola crop unaffected. With no competition from weeds, the GM canola should grow more easily and produce a greater yield of canola oil than a non-engineered crop. Design an experiment to determine whether the herbicide-resistant canola crop produces a greater yield than a non-modified crop.

Genetic Techniques Used in Molecular Biology

The transfer of DNA fragments between bacteria species is at the heart of much current work in molecular biology. As shown in Figure A2.23, the data collection for this research involves specialized equipment and carefully developed techniques. In the next activity you can learn more about how this research is conducted.

Figure A2.23: A researcher collects data using a fluorescent dye to determine the quantity of specific proteins from a DNA sample.

Investigation

Risk-Benefit Analysis—Genetically Modified Foods

Purpose

You will use information presented in this chapter and from the Internet to gather data regarding the risks and benefits of genetically modified foods. You will develop a position on this issue and then defend this position in light of information presented by other students.

Science Skills

- ✓ Initiating and Planning
- ✓ Performing and Recording
- ✓ Analyzing and Interpreting
- ✓ Communication and Teamwork

Identify Alternatives/Perspectives

1. To what extent should genetically modified (GM) foods be developed and used? Begin to brainstorm alternative solutions to this question. One approach is to consider the question from as many points of view as possible. Think of several different groups or individuals who have a particular view or interest on the use of genetically modified foods. Create a table with "Stakeholder" at the top of one column and "Point of View/Perspective" at the top of the other column. Complete the table by listing at least three stakeholders and their viewpoints.

Research the Issue

2. Conduct research to collect and assess information for all the perspectives of stakeholders you have identified. Assemble the relevant information as points on a page. People use a variety of terms when referring to genetically modified foods. For a more effective Internet search, you should perform several searches using the many variations on terms in your search engine: *genetically modified foods*; *GM foods*; *genetically engineered foods*; *GE foods*; *biotech foods*; *biotechnology*; *genetically modified organisms*; *GMO*; and other examples.

Analyze the Issue

3. **a.** Analyze the results of your research by concisely organizing your findings in a second table, with "Risks" at the top of one column and "Benefits" at the top of the other.
   b. Review the risks and benefits. How would each stakeholder react to the entries? Record the reactions of three of your stakeholders to the data on your Risk/Benefit table.

Take a Stand and Defend Your Position

4. To what extent should genetically modified (GM) foods be used? What is your position? Take a clear position on this issue by writing a few concise paragraphs. Your position should be supported by the body of research and should indicate that you have considered the question from more than one viewpoint.

Evaluation

5. It is very helpful at this stage to share your findings with other students. How do their points of view differ from yours? Are the arguments made to support these views consistent with the information that you researched? Did other students find additional information that was unknown to you? How has your position changed since you started? If you had to make this decision again, what would you have done differently?

   Write a few concise paragraphs to evaluate your position and the process you used to develop this point of view. Your response should indicate that you have considered the positions of other students and that these alternative viewpoints have been addressed.

2.5 Summary

Each person's DNA is unique, and the technology of DNA fingerprinting can be used for identification purposes.

People can genetically alter the genetic traits of an organism. This genetic modification can be done using selective breeding within a species or a closely related species. When genetic modification is done by inserting a gene or genes from one species into another species, it is called transgenics. Transgenics can be used to produce genetically modified organisms, or GMOs, used for new kinds of foods, medicines, or materials.

Some people oppose the production of genetically modified organisms. Concern about the development of genetically engineered organisms tends to focus on issues regarding possible dangerous or as yet unknown effects on people or the ecology. Some people feel that it is cruel to make experimental organisms, or they disagree with changing organisms at all. Others fear that genetic engineering technology will be used to make bioweapons. Opposition can also be based on moral or religious reasons.

Transgenics is accomplished by making recombinant DNA, which is a combination of genes from two or more species spliced together.

Recombinant plasmids are used in bacteria to produce large amounts of needed medical enzymes such as insulin.

Repairing defective genes by inserting a non-defective copy into a person's DNA is called gene therapy. Therapeutic genes are inserted with the help of virus vectors that have had their disease-causing genes removed. The viruses deliver the therapeutic gene to cells in patients.

2.5 Questions

Knowledge

1. Match the following terms with the example that best describes each term.

- transgenics
- genetic modification
- DNA fingerprinting
- recombinant DNA
- gene therapy

a. A farmer uses a plastic bag to collect pollen from his fastest-growing corn plants and then sprinkles some pollen on the corn silk of his most disease-resistant corn plants. He collects the seeds produced from this cross-pollination and grows his next crop from these seeds.

b. Enzymes are used to cut up DNA left at a crime scene, and then the DNA is run through a gel. The distinctive pattern of bands produced is used to compare with the patterns of suspects in the crime.

c. A modified virus is used to deliver a non-defective version of the gene that causes cystic fibrosis in body cells.

d. A researcher uses enzymes to cut some human DNA into smaller pieces and then uses different enzymes to splice the DNA into a bacterial plasmid. The new DNA is a combination of bacterial DNA and human DNA.

e. A gene from the bacterium *Bacillus thuringiensis* (Bt) produces a protein with insecticidal properties. The bacterial gene is isolated and spliced into the DNA of a cotton plant. When the cotton plant is grown, it produces the bacterial insecticide.

2. List some potential advantages of genetically modified plant crops.

3. Describe one possible risk of applying transgenics to produce a new type of organism.

4. Explain why virus vectors need to be used in gene therapy.

Applying Concepts

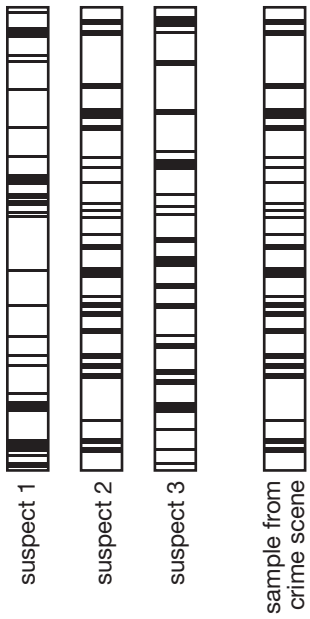
5. A sample of biological material was left at a crime scene. The DNA from this sample was isolated and a DNA fingerprint was created. The three crime suspects all volunteered to let their DNA be taken, and a DNA fingerprint was created for each person. Compare the unique banding pattern produced for each suspect to identify the suspect who was at the crime scene. This information can be seen in "DNA Fingerprint Patterns."

6. Explain why a person who receives gene therapy will not pass on to her offspring the repaired gene that has been inserted into her cells by a virus.

7. The gene that produces a blood-clotting factor that some people who have hemophilia lack has been isolated. Explain the steps used to develop a strain of genetically engineered bacteria that produce large amounts of this factor to treat people with hemophilia.

8. Most of the citizens of Iceland have volunteered to have their genetic information collected and compiled in an electronic database. The genetic make-up of Iceland's population has changed little since the Vikings colonized the island in the ninth century. This history makes it easier for researchers to identify gene mutations that may be associated with diseases. Describe one risk and one benefit of a nation possessing a gene bank for its citizens.

DNA Fingerprint Patterns



Chapter 2 Summary

In this chapter you have examined the structure and function of DNA and have applied your understanding of the mechanisms of DNA inheritance to predict the probability of offspring inheriting traits caused by a single gene. You have also seen how mutations can affect the functioning of DNA and how certain diseases can arise from inherited mutations rather than from environmental factors. You used tools, such as a Punnett square and a pedigree chart, to predict and trace the inheritance of traits in individuals within a family. In Lesson 2.5 you examined the use of genetic technologies and looked at the ethical implications related to their use. Throughout the chapter you learned about the contribution of Mendel and other scientists to the field of genetics.

In future units of Science 30, you will learn more about factors that increase the likelihood of mutation. These factors include chemical substances used in the production of commonly used materials—or substances considered to be pollutants—and some forms of radiation within the electromagnetic spectrum.

Summarize Your Learning

In this chapter you learned a number of new biological terms, processes, and theories. It will be much easier for you to recall and apply the information you have learned if you organize it into patterns.

Since the patterns have to be meaningful to you, there are some options about how you can create this summary. Each of the following options is described in "Summarize Your Learning Activities" in the Reference section. Choose one of these options to create a summary of the key concepts and important terms in Chapter 2.

Option 1: Draw a concept map or a web diagram.	**Option 2:** Create a point-form summary.	**Option 3:** Write a story using key terms and concepts.	**Option 4:** Create a colourful poster.	**Option 5:** Build a model.	**Option 6:** Write a script for a skit (a mock news report).

Chapter 2 Review Questions

Knowledge

1. Describe the differences among the terms *chromosome*, *DNA*, and *gene*.
2. How many chromosomes are found in a human autosomal cell?
3. Compare the processes of mitosis and meiosis.
4. What are the differences between acquired and inherited characteristics?
5. A pea plant with green pea pods is crossed with a pea plant with yellow pea pods. Both plants come from lines of pea plants that have only produced one colour of pod. All offspring from this cross develop green pea pods.
   - **a.** Determine whether the green colour for pea pods is dominant or recessive.
   - **b.** Using letters to represent alleles, write the most likely genotypes for the two parent plants and the genotype of the offspring.
6. Distinguish between the terms *genotype* and *phenotype*.
7. For each of the following DNA nucleotide sequences, write the sequence for the complementary strand and for the chain of amino acids that code for this strand.
   - **a.** ATATACCAGCCGATA
   - **b.** GCATGGTTCATAAGG
   - **c.** CGTATGCCAGTTTAT
   - **d.** GGTTTATGCATTTCT
8. For each of the following amino acid chains, write all the corresponding DNA sequences that could code for that chain.
   - **a.** Methionine-Threonine-Glutamine
   - **b.** Arginine-Lysine-Tryptophan
   - **c.** Serine-Proline-Aspartate
   - **d.** Leucine-Cysteine-Valine
9. Describe the importance of proteins.
10. Compare and contrast a point mutation and a frameshift mutation.
11. List the steps used to create recombinant DNA.

Applying Concepts

12. Draw a series of diagrams to compare and contrast mitosis and meiosis. For each step, use one pair of chromosomes and include labels to describe the process.
13. A rare recessive allele causes a lack of fur pigment in tigers to produce the distinctive "white tiger" phenotype. These animals have sometimes been incorporated into the extravagant stage shows of Las Vegas magicians.
    - **a.** Explain why entertainers who use the white tigers in their shows only want their white tigers to breed with other white tigers or the offspring of white tigers.
    - **b.** State possible problems with the selective inbreeding of closely related white tigers.

14. A dog breeder owns a dog that has just given birth to a litter of puppies. Both the father and the mother were selected from long lines of well-known and recorded pedigrees. One of the puppies has a red fur colouring that the breeder has never seen in any of the puppy's ancestors.
    - **a.** Explain the likely cause of this new trait.
    - **b.** Describe how you can determine if the new colour trait is dominant or recessive. Use Punnett squares to illustrate your answer.
    - **c.** Explain the steps you would take to develop a breed of dogs with this particular trait.
15. The use of antibacterial soaps has become popular. Describe how bacteria can develop a resistance to antibacterial soaps. Include the role of bacterial plasmids in your answer.
16. Draw a series of images that illustrate the process of gene therapy on a patient who has the autosomal recessive disease of cystic fibrosis.

17. A breeder of Labrador retrievers is told that black fur is dominant over yellow fur. The breeder crosses a black Lab with a yellow Lab. When the puppies are born, some are black, some are yellow, and some are chocolate in colour. Evaluate the following statements regarding this Labrador cross. State whether you agree or disagree with each one. For those statements you disagree with, explain why.

a. The gene for coat colour in Labrador retrievers must be controlled by more than one gene or have more than two possible alleles.

b. All the puppies have homozygous genotypes for their coat colour.

c. The female must have bred with both a black Labrador male and a chocolate Labrador male to produce three kinds of coats in her puppies.

d. A pedigree of coat colours is helpful to determine the genotype of the parents and offspring.

18. The allele that produces hairy ears in humans is found on the *Y* chromosome.

a. State which gender is affected by the presence of a gene on the *Y* chromosome.

b. Explain why a Y-linked gene cannot be recessive or dominant.

c. State the probability of a male with hairy ears passing this trait onto his son.

d. State the probability of a male with hairy ears passing this trait onto his daughter.

e. Can a person be a carrier for this trait? Explain your answer.

19. Elliptocytosis is a genetic disorder affecting a protein that influences the cell membrane structure in red blood cells. Red blood cells with the altered protein have an elliptical, or oval, shape when compared to red blood cells containing the unaltered protein.

The pedigree in Figure A2.24 shows how elliptocytosis is inherited within one family.

a. Based on the evidence shown in this pedigree, determine which pattern of inheritance—sex-linked, autosomal recessive, or autosomal dominant—is exhibited by elliptocytosis. Explain how evidence in the pedigree supports your answer.

b. Predict the possible genotypes and phenotypes of offspring in generation V.

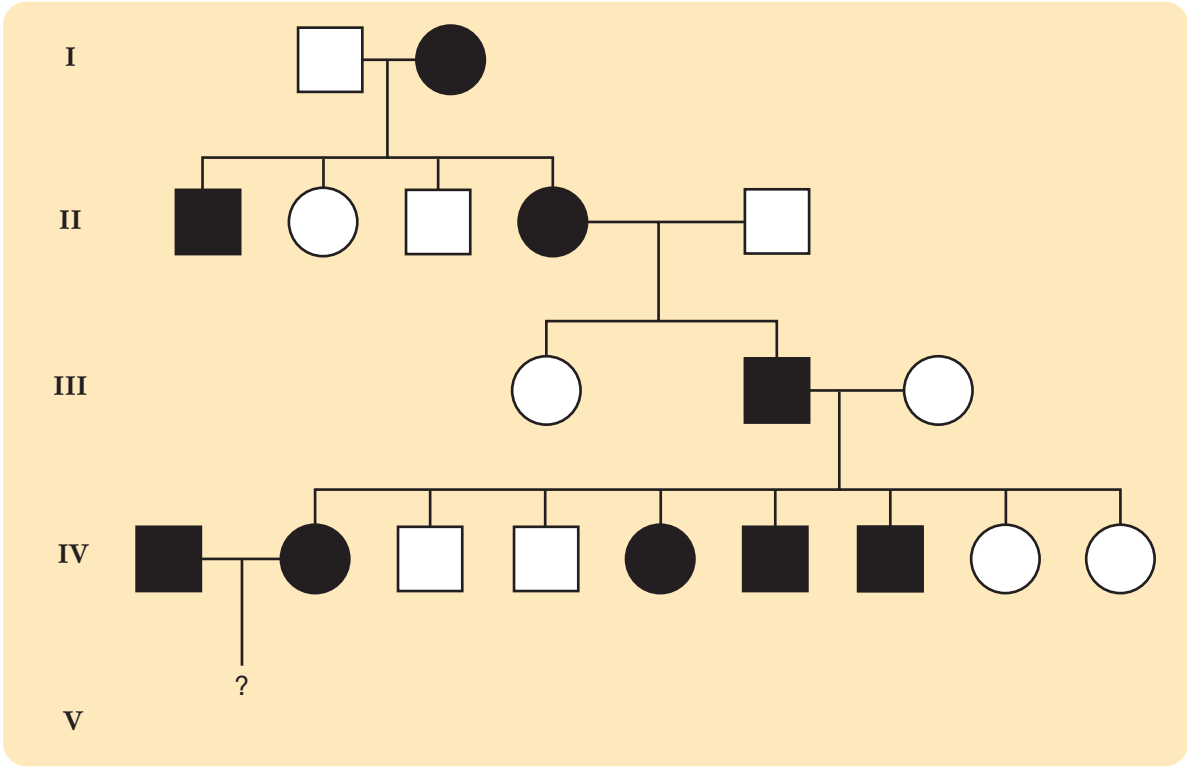


Figure A2.24